DAMES & MOORE

APPENDIX A

February 21, 1980
1097-061-12

Dow Chemical U.S.A.
B-1226 Building, Texas Division
Freeport, Texas 77541

Attention: Ms. Karen Schubart

Gentlemen:

Preliminary Report
Hydrogeologic and Engineering Studies
Proposed Hazardous Waste Landfill
For Dow Chemical, Texas Division

We are pleased to present eight copies of our preliminary report, "Hydrogeologic and Environmental Studies, Proposed Hazardous Waste Landfill, for Dow Chemical, Texas Division."

The contents of this report were discussed with Dr. Bone and other representatives of Dow in meetings and by telephone during early February. We understand that Dow intends to adopt the recommendations presented in this report. Implementation of the recommendations will include relocation of the site to the west so as to avoid areas underlain by the deep section of sandy fluvial deposits. Further, as no leachate detection system will be included in the design, a more comprehensive shallow ground water monitoring system than required under RCRA will be installed.

The first phase of the landfill will occupy approximately 3 acres in the northwest corner of the 17-acre parcel investigated for this report. This area is not underlain by Recent river deposits. Additional borings are presently being drilled to the west of the old site to explore the continuity of the clayey Pleistocene deposits and to determine whether any concealed, relic meanders of the Brazos River are present. During this drilling program, the ground water monitoring system is being installed.

The log of borings drilled to date indicates no shallow sand strata, and it appears likely that the remaining intermediate borings will confirm the relative uniformity of the soil conditions over the new site area. We therefore recommend that Dow finalize their designs, and adopt a construction schedule which will ensure that the landfill is available for service when required.

In the event that any unexpected soil conditions are encountered in the remaining borings which would cause us to modify our recommendations, we will notify Dow in writing at the earliest opportunity.

A final report will be submitted following completion of the supplementary boring program and any associated testing. The report will include preliminary background water quality analyses from the new monitor wells. We anticipate that this report will be available three to four weeks after completion of the field work.

It has been a pleasure working with you on this interesting project, and we look forward to continuing our association with Dow on future related projects. If you have any questions concerning this report, or if we can be of additional assistance, please do not hesitate to contact us.

Yours truly,

DAMES & MOORE

Stuart Edwards
Project Manager

James R. Hussey, P.E.
Partner

SE:JRH:mrf

SITE DESCRIPTION

The proposed landfill will be constructed at the Dow Chemical Plant B, located in Brazoria County approximately 8 miles north of the Gulf of Mexico (Plate 1, Vicinity Map). The town of Clute is located approximately 2 miles to the north; Velasco and Freeport are approximately 2 to 3 miles to the east. The topographic map (Plate 2, Site Map) is a photo enlargement of a 1:24000 scale blueprint provided by Dow Chemical. This enlargement provides a scale of 1:6000 (1 inch = 500 feet) and can be found in a pocket at the rear of this report.

The facility will occupy approximately 17 acres within an 80-acre parcel of land adjacent to the Brazos River that has been set aside for long-term development as a landfill, but which was originally graded and used as a surface impoundment for wastewater treatement. The impoundment is registered with the Texas Department of Water Resources. The parcel is bounded by the Brazos River to the west and a drainage canal to the north. The adjacent land to the east is presently used as a burning ground and solid waste disposal site, with two incinerators located approximately 100 feet from the easterly site boundary. At the solid waste disposal site, the land surface adjacent to the incinerators has been raised by approximately 12 feet above the natural surface elevation by fill materials. This raised area forms part of the dike system that has been built around the perimeter of the 80-acre parcel.

The parcel is located within the meander belt of the Brazos River. Natural vegetation was stripped during site grading for the originally planned surface impoundment. Surface elevations range between 8 and 11 feet above mean sea level, and an earth dike 5 to 12 feet in height has been constructed around the perimeter. The dike serves to contain direct rainfall which is channeled by a ditch along the inside perimeter of the diked area. Stormwater may be discharged from a trap into the drainage canal to the north.

During drilling, the site was extremely muddy because of recent rain, and a large part of the site was inaccessible to the truck-mounted drilling rig. Vehicular traffic was restricted to the dikes and along narrow sections of raised land within the site.

GEOLOGY

The Do Chemical (Texas Division) plant at Freeport, Texas lies within the Gulf Coast physiographic province. This province is charac terized by relatively flat, featureless plains bordering the Gulf Coast basin and the Gulf of Mexico. The overall depositional history of the Gulf Coast has been one of gulfward migration of shorelines and the continental shelf edge, leaving thick accumulations of sediments dipping gulfward with inclinations generally of less than 2 degrees. Further, this migration has superimposed progressively landward depositional environments (generally sandy) over an open marine depositional environ- ment (generally clayey) in an extremely complex and dynamic interplay involving basinal filling, regional subsidence, shifting depositional environments, sea level fluctuations and development of structures by salt and/or shale diapirism.

Development of subsurface fault zones is a recognized method of stress relief in an actively growing/subsiding basin. As sediments are carried and deposited beyond the continental shelf, stresses build up nearshore due to the increased weight of the accumulating basinal sedimentation. These faults, which are known as growth faults, are usually very long, but produce little surficial expression due largely to the general plastic character of the overlying Quaternary deposition. Subsurface faulting is also associated with diapir salt/shale uplifts (salt domes) and consist of arcuate and smaller radiating faults.

Recent oil studies indicate that the triggering of active surface faulting is influenced by local subsidence directly related to the oil, water and gas production rates from an area. The rapid lowering of piezometric surfaces of Gulf Coast aquifers can be a possible mechanism for fault activation and deformation.

In the vicinity of the site the areal distribution of the various surficial deposits has been completely dominated by the historical wanderings of the Brazos River. These Recent deposits, including inter-distributary clays, silts and sandy silts, alluvial sands and silty sands and deltaic organic silts and silty clays, extend to depths of up to 120 feet. Deep borings (>500 feet) in the area reveal that alternating clays, silts and sands of the Beaumont, Montgomery and Bentley formations extend to depths of 500 to 600 feet where the Willis Sand is first encountered. The Willis continues to a depth of approximately 1,100 feet representing the base of the Chicot Aquifer (see Geohydrologic Column, Plate 3).

Bryan Mound, a shallow piercement dome, is located approximately 5 miles south-southeast of the site. Deep subsurface faults are known to radiate from this dome in several directions. However, the displacement observed at these depths (2,000 to 3,000 feet) produces little, if any, surficial expression due largely to the plastic nature of the overlying Quaternary sedimentation. Further, the mechanism of Gulf Coast "growth faulting" is characterized by landslides or gravity-slides which produce a situation whereby the displacement is reduced or "dies" as the surface is approached.

Literature reveals the existence of just such a deep-seated feature located north of the site, subparalleling the coastline. The feature is presumably a growth fault. It lies outside of the required mile boundary and is therefore of no consequence to this report. Upon close scrutiny of available maps and aerial photography (both black-and-white and color infrared), the two crossing-tonal anomalies mentioned in our proposal for this project have been, in our opinion, photogrametrically misinterpreted and are actually pipelines.

Detailed information relating to site geology is presented in a subsequent section, "Site Conditions."

HYDROLOGY

SURFACE WATER

Drainage patterns within 1,000 feet of the project area are controlled by the Brazos River. Point source runoff containment will be a construction design consideration. Drainage of the Brazos River and Oyster Creek is towards the south-southeast, with a minor portion of the area west of the Brazos draining in a south-southwesterly direction via Jones Creek. All streams and natural drainage systems eventually empty into the Intracoastal Waterway and the Gulf of Mexico. Surface drainage features are shown on Plate 2.

The Freeport area has been subject to frequent and serious flooding. The construction of control structures along the Brazos, together with protection in the form of levees, has mitigated the problem to a large extent.

The U.S. Corps of Engineers performed a preliminary flood study for the Freeport area and estimated that the 100-year surge elevation will be 14 feet above sea level (Exhibit 1). The highest recorded flood level in the area reported on Exhibit 1 (17.2 feet) was prior to construction of the control structures on the Brazos

According to the Federal Insurance Administration Insurance Rate Map for the City of Lake Jackson, the 100-year flood elevation at the site is approximately 13 feet.

GROUND WATER

Formations providing potable ground water in Brazoria County range in age from Pliocene to Holocene. These units are: the Goliad sand, Willis sand, Bentley formation, Montgomery formation, Beaumont clay and the Quaternary alluvium. These are grouped together to form the Chicot Aquifer (upper and lower units) and the Evangeline Aquifer as shown on the Geohydrologic Column (Plate 3). In some places, one or more of these formations may be absent due to nondeposition or erosion. The formations are similar in composition; sand, silt, and clay or shale comprise most of the sediments. Other materials such as gravel, marl, and shell are also present in lesser amounts. The formations generally show greater depth and thickness in a gulfward direction. Individual beds of sand and clay are rarely continuous over long distances. Although there is some vertical interchange of water, this exchange is largely confined due to the lenticular nature of the sand beds and the presence of interbedded clays.

The Evangeline Aquifer is a sequence of alternating beds of sand and clay which generally contain potable water. In the project area, the top of this aquifer is approximately 1,000 to 1,200 feet beneath the surface. It has not been developed in the Freeport area as it has been found to contain saline water.

In the project area, the upper and lower units of the Chicot Aquifer differ from the Evangeline in permeability, piezometric level, stratigraphic section and chemical characteristics in the project area. These two units usually are separated by clay. The upper unit can either be a water table or artesian aquifer; the lower unit is an artesian or leaky artesian aquifer. In the project area, the upper unit consists of the interconnected shallower sands that are usually found between the surface and a depth of 250 to 300 feet. Extensive pumping from the Upper Chicot in the Freeport area has produced a regional cone of depression which extends beneath the plant site (Plate 4) where the piezometric surface is at approximately Elevation -45 feet (MSL).

Borings performed at the site by Soil Mechanics in 1979 and Dames & Moore for this report reveal discontinuous sands at an elevation 0 to 5 feet below sea level and massive sands 5 to 10 feet thick occurring at elevations approximately 15 to 20 feet below sea level over the eastern portion of the site. The sands are part of the Recent alluvium deposited by the Brazos River. Hydraulic connection between these sands and the upper unit of the Chicot Aquifer cannot be completely ruled out. Before extensive pumping in the Freeport area, a natural dynamic equilibrium existed in the aquifers. The Evangeline, under artesian pressure, seeped upward into the Lower Chicot. Flow in the Upper Chicot, which was under water table conditions in some areas and under artesian pressure in the project area, was in part vertically upwards towards zones of interconnections with the major alluvial systems. Reversal of the hydraulic gradient has occurred as a consequence of lowering the piezometric surface of the Upper Chicot Aquifer. The lower unit is still artesian throughout the project area. The upper unit, however, being the most highly developed aquifer in the area, is producing signs of water table conditions with some recharge most likely taking place from the Brazos and San Bernard Rivers.

It is unlikely that in the vicinity of the site, the Recent sands are in direct hydraulic connection with the Upper Chicot. The moderate to high salinity of the ground water beneath the site would, if this were a significant source of recharge, cause an increase in the salinity of the ground water in the Upper Chicot.

Water quality analyses of samples from the Upper Chicot do not show high chloride content (Table 1). Recent data from the Oyster Creek Division plant (1979) shows that in this area, the chloride level in the Upper Chicot is essentially the same as it was in 1953.

An estimate of the number of wells within 1 mile of the proposed site has been made by Dow and confirmed by the County Health Officer. These wells are generally screened in the Upper Chicot between 160 and 200 feet. A breakdown of the total estimate of 46 wells, by area, is presented in Exhibit 2.

SITE CONDITIONS

Three separate investigations have been performed at the site between 1972 and the present, during which 16 borings were drilled. Locations of the borings and subsurface sections are shown on the Plot Plan (Plate 5). The logs of borings drilled during this investigation are presented in Appendix A. Logs of previous borings are not presented in this report, but have been used in the development of cross sections AA-, BB-, CC- and DD- (Plates 6 through 9).

A review of the boring logs and cross sections reveals a change in soil conditions across the site. In the vicinity of Borings DM-1 and MW-3, the stiff to very stiff clays of the Beaumont formation were encountered at shallow depths. In contrast, Boring MW-1 revealed more than 50 feet of interbedded sands, silts and clay mixtures overlying the Beaumont. An analysis of all the available boring data enabled an isopach to be drawn which shows the top surface of the Beaumont clay (Plate 10). From the configuration of this surface, it is clear that a portion of the site is underlain by an old river meander which has been infilled with a variety of river sediments. Despite the heterogeneity of the river deposits, there appears to be a consistent stratum of clay overlying the whole site which is generally at least 10 feet in thickness.

These surface clays are relatively impermeable, with measured permeability values in the range 1×10^{-7} cm/sec to 1×10^{-8} cm/sec. The shear strength of this material tends to vary depending on the degree of desiccation and the presence of organics. Shear strengths of the materials in the upper 10 feet have been measured in the range 500 psf to 2,500 psf, and seem to average around 1,000 psf. The Beaumont clay is stiff to very stiff, with shear strengths ranging from approximately 1,500 psf to more than 4,000 psf. The river deposits between the

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Beaumont and the surface cap of clay tend to be silty and sandy and medium dense.

The ground water table at the site varies in elevation from approximately +8 in the vicinity of Boring MW-3 to 0 in the vicinity of Boring MW-1, indicating a southeasterly flow of the shallow ground water. This is entirely reasonable in view of the regional drainage (predominantly southerly) and the proximity of the Brazos River. The ground water table over most of the site area appears to be on the order of 4 to 5 feet below the existing ground surface. The deeper ground water levels recorded on some of the boring logs reflect the fact that these borings were drilled from the higher ground around the perimeter of the site.

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DESIGN RECOMMENDATIONS

GENERAL

Pending EPA regulations require that the suitability of a site for hazardous waste disposal be evaluated in far greater detail than generally required in the past. The stated objectives of EPA in preparing the regulations are to protect the quality of ground water and surface water. Accordingly, flood susceptibility, depth to ground water, and the properties of shallow subsurface soils are of paramount importance.

The proposed site is located in an area which is prone to flooding, and the depth to the uppermost ground water table is shallow. However, these apparent deficiencies are, in part, compensated by the local geologic and hydrologic conditions and can, in our opinion, be further mitigated by the use of properly engineered features.

The shallow ground water at the site is moderately to highly saline, and is not believed to be a source of recharge for the Upper Chicot Aquifer in this area. The surface soils in the site area appear to be consistently clayey with discontinuous sands present only below a depth of 8 to 10 feet over the southerly portion of the site. It should be noted that these sands have the potential for contaminant transport, as determined during a previous investigation at the site. The results of this investigation are discussed in greater detail in the following section, "Ground Water Monitoring." The source of contaminants discovered in these sediments is not known, and it is possible that significant lateral movement has taken place. There is a possibility that there are small outcrops of sand within the site area which were not observed during the investigation. If present, such outcrops could provide a conduit for the migration of contaminants from the surface. The necessity for careful inspection of the surface of the landfill during construction is clear. Measures to mitigate the presence of such sand outcrops are discussed in the following paragraphs.

The potentially adverse effects of the interbedded sands underlying the southerly portion of the site may be further mitigated by relocation of the development of the first-phase landfill to the west. The alternate location would be selected such that the cell, or group of cells, would be underlain by the stiff, more homogenous Beaumont clay.

LINER DESIGN

Precipitation in the area exceeds evaporation by approximately 4 inches. A liner design consisting of a liner and leachate collection system would therefore be required under the pending regulations. The liner system may be constructed using suitable inplace or imported soil. Alternatively, a composite soil and membrane liner could be utilized. Since the site is underlain by a stratum of low permeability clay, a 5-foot thick, natural soil liner with a leachate collection system is likely to be the most economic option. Under the pending regulations, the bottom of the liner should, where possible, be separated from the ground water table by a minimum of 5 feet. The natural ground surface in the site area is on the order of 9 to 10 feet above sea level, and the ground water table is at a depth of approximately 4 to 6 feet. The specified separation will require the placement of approximately 5 feet of fill throughout the site, resulting in the import of more than 100,000 cubic yards of clay.

Under the provisions of the pending regulations, the 5-foot separation may be waived if it can be demonstrated that the ground water table will not come in contact with the landfill, and that a leachate monitoring system can be installed satisfactorily. The design of the leachate monitoring/collection system is likely to be a critical factor in the assessment of the applicability of this waiver.

The base of the landfill should be maintained at or above the present land surface. The potential for contact between the ground water table and the landfill will thus be minimized.

Prior to general grading of the liner surface, the entire area should be stripped to a depth of 6 inches to permit a thorough inspection of the soil for identification of any zones of sand which may be present. In the event that a sand zone is encountered, it must be excavated to a depth of 5 feet and replaced with compacted clay. A further advantage of relocating the site to the west is that the possibility of encountering such a feature is minimized.

The clay liner must be graded to drain so that the leachate collection system will function properly, and leachate will not be permitted to pond on the surface of the liner. The design grade should be no less than 1 percent towards the central collection system. The 12 inches of porous medium required by the regulations for the leachate collection system should be placed over the graded liner surface. The use of a lightly compacted medium to coarse sand is recommended for this purpose.

An alternate design for the liner system is shown on Plate 11 and is discussed in the section, "Leachate Monitoring." This design will be required only in the event that a leachate detection system is required by regulation, in addition to the collection system.

LEVEE DESIGN

According to the pending regulations, the perimeter levees should be designed to protect the facility from a 500-year storm. The magnitude of a 500-year storm surge has not been calculated for this area. We therefore recommend that the flood protection system be based on the 100-year surge elevation of +14 feet with a 2-foot freeboard above that elevation.

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It should be noted that the site preparation for the liner (grading of the liner surface and installation of the leachate collection system) will be relatively expensive. Therefore, there may be some significant advantage to raising the levees above the recommended elevations to minimize the area of landfill required.

We recommend that the levees be constructed using compacted clay, with outside slopes of 2 horizontal to 1 vertical and inside slopes of 1-1/2 horizontal to 1 vertical. There will be no significant advantage of providing a keyway around the foundation of the levee, providing that any sand zones in the foundation have been treated as outlined previously. The outside slopes should be vegetated to minimize erosion.

FILL PLACEMENT

Surfaces to receive fill should be scarified to a depth of 12 inches, moisture conditioned to near optimum moisture content, and compacted to a dry density of at least 90 percent of the maximum dry density as defined by the ASTM 1557-70 compaction tests. Fill should be placed in 8-inch loose lifts slightly above optimum moisture content and compacted to at least 90 percent relative compaction.

Inspection of the site for sand outcrops should be performed by a qualified soils engineer. All fill placement operations should be observed continuously by the soils engineer.

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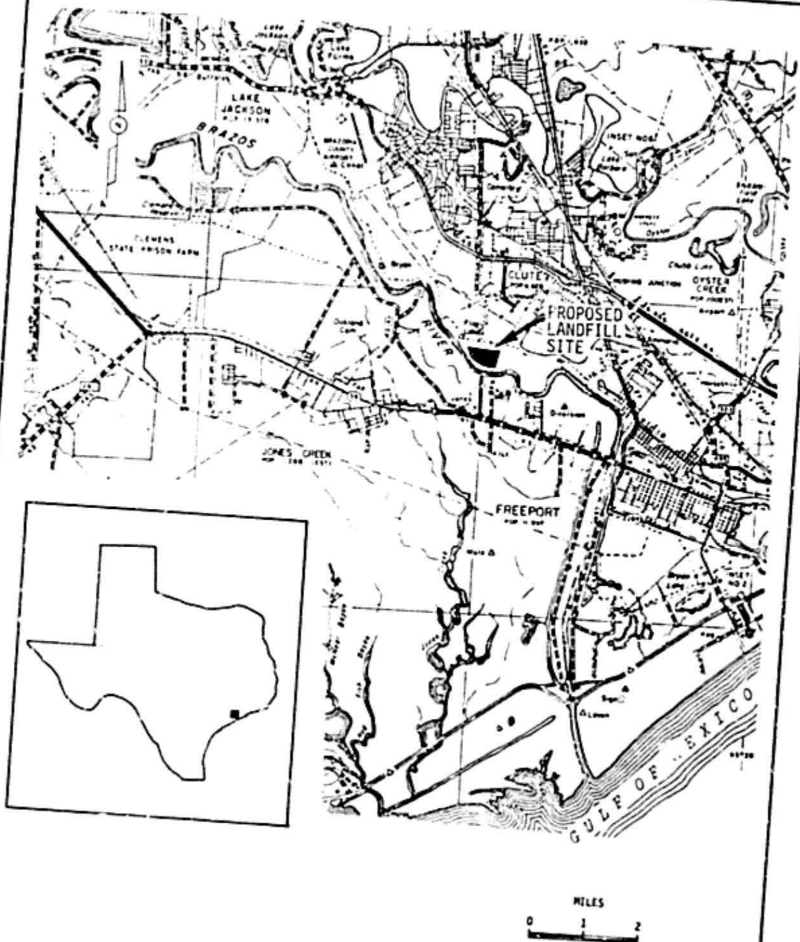

VICINITY MAP

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SYSTEM	SERIES	STRATIGRAPHIC UNIT	AQUIFER	UNIT	APPROXIMATE ELEVATION (FT)
QUATERNARY	HOLOCENE	QUATERNARY ALLUVIUM	CHICOT	UPPER	
	PLEISTOCENE	BEAUMONT CLAY			-300
		MONTGOMERY FORMATION		LOWER	
		BENTLEY FORMATION			
TERTIARY	PLIOCENE	WILLIS SAND			-1000
		GOLIAD SAND	EVANGELINE		
	MIOCENE	FLEMING FORMATION			

GEOHYDROLOGIC COLUMN

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PLATE 3

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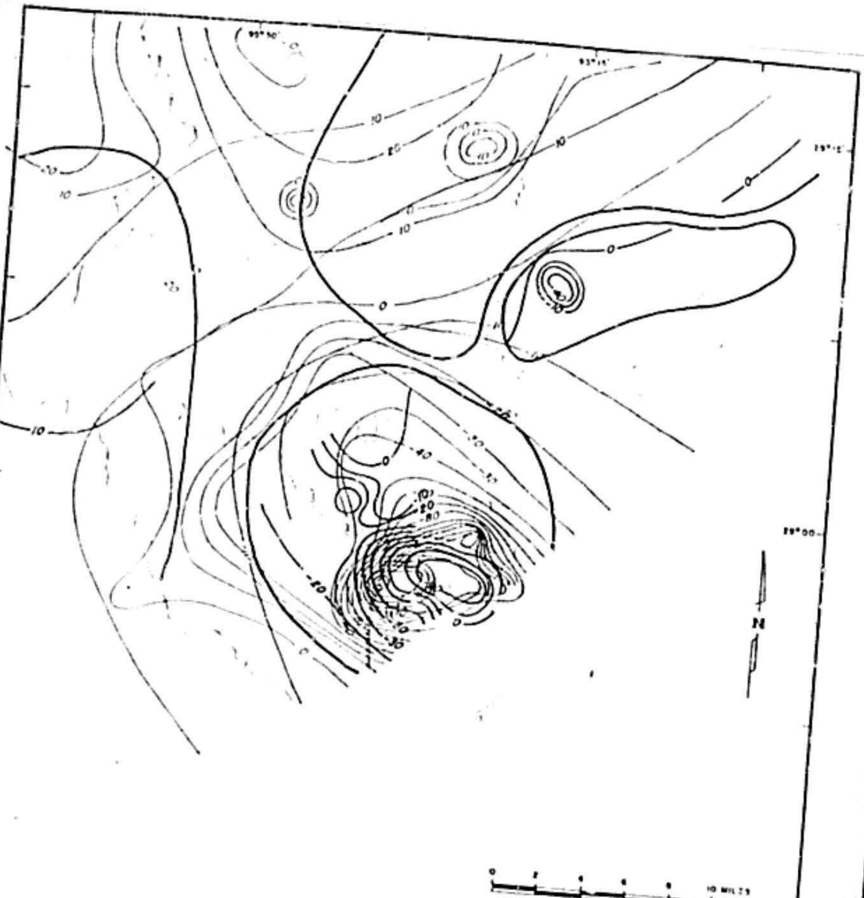

LEGEND

WATER LEVELS 1941-43

WATER LEVELS 1954-55

WATER LEVELS 1967

NOTE: MODIFIED FROM "FIGURES 14,15 AND 16", PRESENTED BY THE TEXAS WATER DEVELOPMENT BOARD IN REPORT 163, GROUND-WATER RESOURCES OF BRAZORIA COUNTY, TEXAS

WATER LEVELS IN WELLS SCREENED IN THE UPPER UNIT OF THE CHICOT AQUIFER

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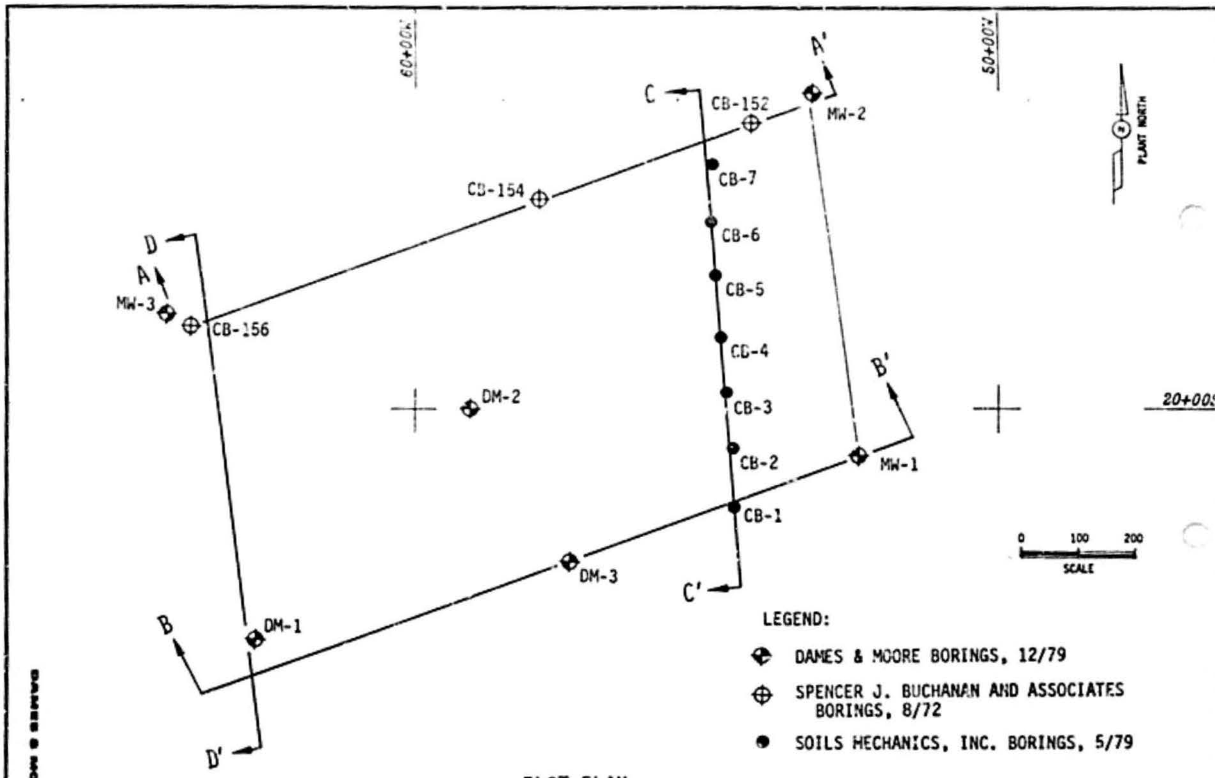
PLATE 4



PLOT PLAN

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PLATE 5

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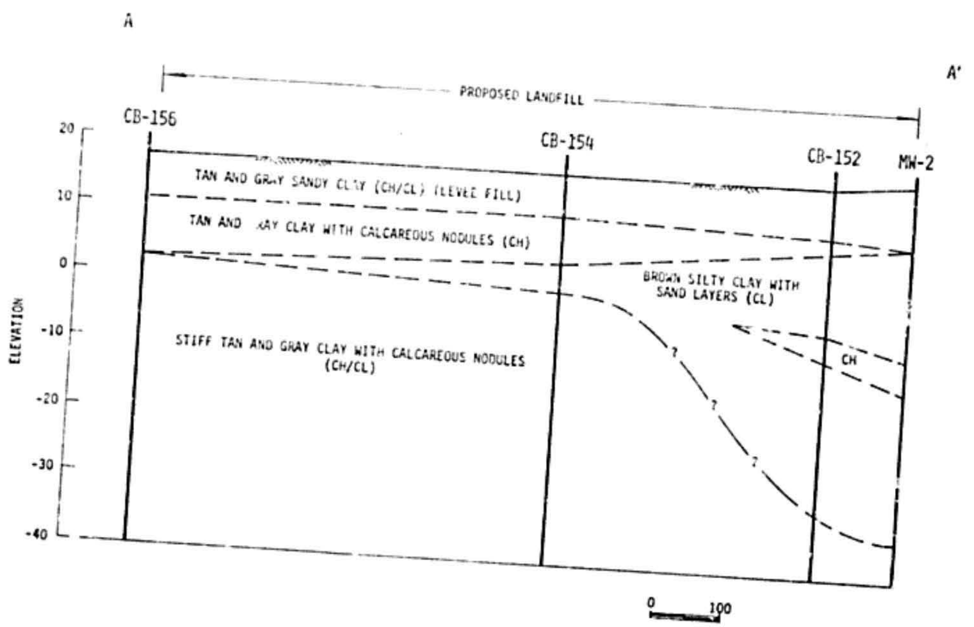

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CROSS SECTION A - A'

APPENDIX B

APPENDIX A

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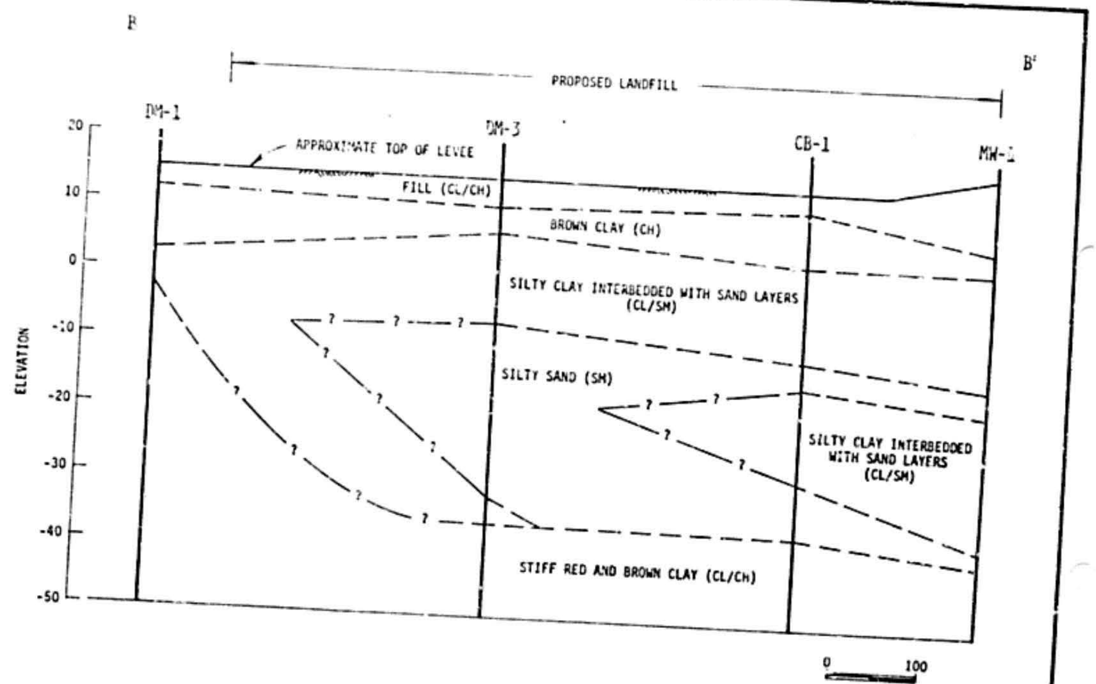

CROSS SECTION B - B'

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PLATE 7

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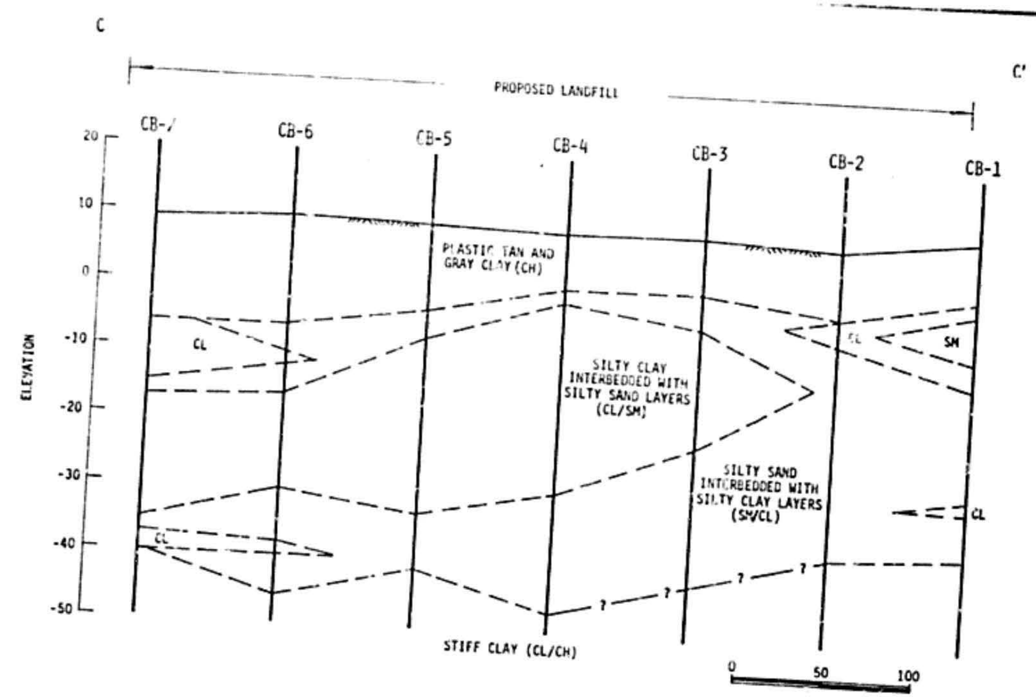

CROSS SECTION C - C'

PLATE 8

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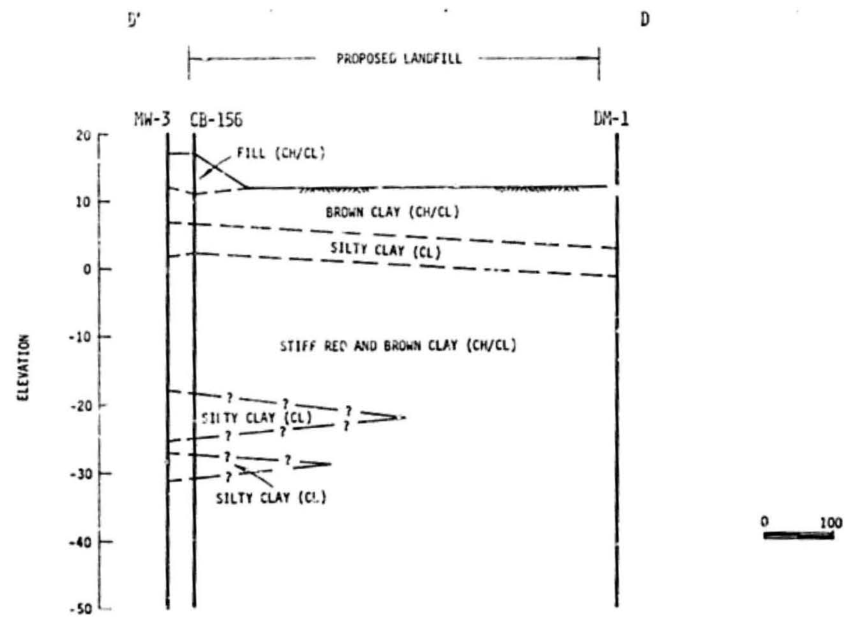

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PLATE 9

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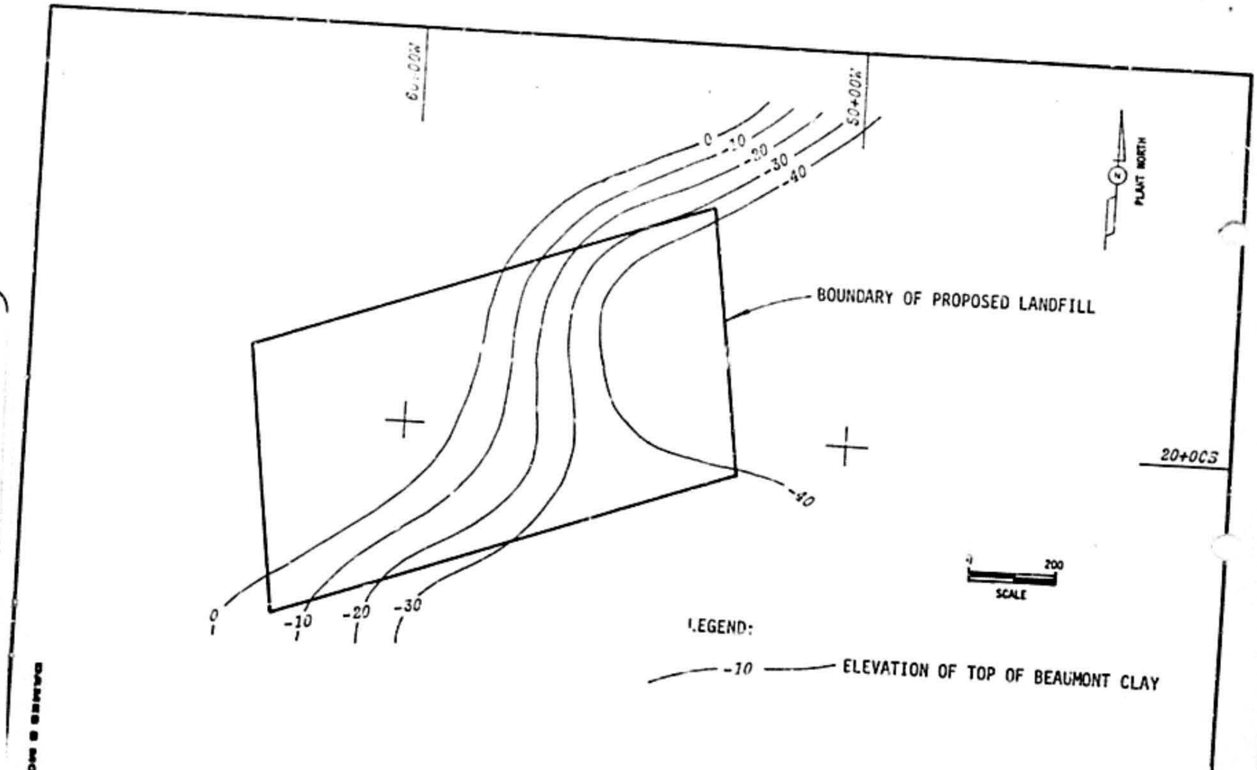

ISOPACH - TOP OF BEAUMONT CLAY